INDOOR AIR QUALITY ASSESSMENT

Riverbend Elementary School
Athol-Royalston Regional School District
174 Riverbend Street
Athol, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of a parent, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at the Riverbend Elementary School (RES), 174 Riverbend Street, Athol, Massachusetts. Concerns about poor indoor air quality and possible microbial/mold growth prompted the request.

On April 11, 2003, a visit to conduct an indoor air quality assessment was made to this school by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA. Mr. Feeney was accompanied by Phillip Leger, Health Agent for the Athol Board of Health during the assessment.

The school is a two-story brick structure originally constructed in 1906. A wing appears to have been added to the rear of the building, possibly during the 1950s. Energy efficient windows were added to the building, most likely during the 1970-80s. The building underwent renovation in the 1950s. Windows are openable throughout the building.

The Athol Board of Health has instituted a regular indoor air quality program at schools within Athol for the past several years. The following recommendations were made by the Athol Board of Health to improve indoor air quality at the RES:

1. Mop floors daily;
2. Improve airflow around radiators to improve heat distribution;
3. Clean ventilation ducts and vents;
4. Empty drip pans for radiators daily;
5. Open windows to provide fresh air;

6. Store gasoline powered equipment outside of building;
7. Keep boiler room door closed; and
8. Institute an indoor air quality team in line with recommendations found in the U.S. Environmental Protection Agency's "Tools for Schools" document (ABH, 2000).

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor Model 8551.

Results

The school has a student population of 212 and a staff of approximately 20. The tests were taken during normal operations at the school. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were above 800 parts per million of air (ppm) in eight of eleven areas surveyed, indicating a ventilation problem in the building. Please note that rooms with carbon dioxide levels below 800 ppm had windows opened. The ventilation system in the building was not operating during the evaluation. Carbon dioxide levels in the building would be expected to be higher during winter months, when windows are closed, due to the configuration and condition of the ventilation system.

Two forms of mechanical ventilation systems exist in the building. Mechanical ventilation in the 1906 wing was originally provided by an air-handling unit (AHU) located in a room on the ground floor. Fresh air is drawn into the building through a louvered vent in the basement (see Picture 1). Air is drawn through heating elements into a fan unit that distributes the air via wall mounted fresh air grilles in classrooms. Classroom fresh air supply grilles (see Picture 2) are connected to the fan unit by ductwork. The ventilation system appears to have been abandoned as part of an energy conservation project based on the following observations:

- The fan belt connected to the motor that drives the fan unit was removed (see Picture 3).
- Energy efficient windows were installed over fresh air intake vents (see Picture 1).
- The system may have also been abandoned due to the presence of pipes insulated with asbestos-containing materials. The pipe wrap appeared to be intact and was well labeled.

These alterations have resulted in windows serving as the sole source of fresh air in the building.

Pressurization created by the original fresh air supply system also originally provided classroom exhaust ventilation. Each classroom contains an exhaust vent located at floor level that is connected by ventilation shafts to the basement heating elements. A number of these vents were obstructed by cabinets, bookcases and other items. Negative pressure is created in these shafts as heated air rises (called the stack effect), which in turn draws air into the exhaust vents of each classroom. Because the system has been abandoned, no means of mechanical supply or exhaust ventilation exists.

During summer months, ventilation within the 1906 section is controlled by the use of openable windows in classrooms. This section was originally configured in a manner to use cross-ventilation to provide comfort for building occupants. The building is equipped with windows on opposing exterior walls. In addition, the building has hinged windows located above the hallway doors. This hinged window (called a transom)(see Picture 4) enables occupants to close the hallway door while maintaining a pathway for airflow. This design allows for airflow to enter an open window, pass through a classroom, through the open transom, enter the hallway, pass through the opposing open classroom transom, into the opposing classroom and exit the building on the leeward side (opposite the windward side) (see Figure 1). With all windows and transoms open, airflow can be maintained in a building regardless of the direction of the wind. This system fails if the windows or transoms are closed (see Figure 2). Each classroom would have a long pole with a hook that was used to open the hoop latch that locks the transom. All of the transoms in the 1906 building have been permanently sealed.

The 1950's section has fresh air supplied by a unit ventilator (univent) system (see Picture 5). Within each univent is a fan. Opposite this fan is a set of moveable louvers through which fresh air enters the univent. Univents are designed to draw air from outdoors through a fresh air intake located on the exterior wall of the building and return air through an air intake located at the base of each unit (see Figure 3). Fresh and return air are mixed, filtered, heated and provided to classrooms through a fresh air diffuser located on the front of the unit.

Univents were found deactivated, which prevents a continuous source of outside air to provide ventilation. In addition, the fresh air intakes were sealed with plywood (see Picture 6). In order for univents to function as designed, univent fresh air diffusers and return vents must be unblocked and remain free of obstructions. Importantly, these units must be activated and allowed to operate.

Exhaust ventilation in the 1950s section is provided by a natural/gravity feed system. Exhaust ventilation is drawn from the classroom into an ungrated hole located at floor level. A heating element within the shaft creates ventilation via the stack effect.

To provide ventilation during warm weather, the 1950s wing is also equipped with openable windows. Since the exhaust ventilation system is non-mechanical, no airflow is created by this system once the boiler system is deactivated. Therefore, to increase airflow, cross ventilation using windows would be used in this section of the building. Doors in the 1950s section are not equipped with transoms. In order to create cross ventilation, classroom hallway doors and windows need to be opened. Classroom doors were closed in a number of areas at the time of the inspection.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last servicing and balancing was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function

(SMACNA, 1994). Please note that the ventilation systems, in their condition at the time of the assessment, cannot be balanced.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix I.

Temperature readings ranged from 68^{o} F to 75^{o} F during the assessment, which were close to the BEHA recommended comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control is often difficult in an old building without a functioning ventilation system.

The relative humidity ranged from 20 to 36 percent, which was below the BEHA recommended comfort range in all areas surveyed. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Several areas show signs of historic water damage to wall plaster from roof leaks (see Picture 7) and steam pipe leaks (see Picture 8). Wall plaster is not a good mold growth media, however, water trapped behind wallpaper or paint can become a vehicle for mold growth.

Plants were noted in several classrooms. Plants can be a source of pollen and mold, which can be respiratory irritants for some individuals. Plants should be properly maintained and equipped with drip pans. Plants should also be located away from radiators to prevent the aerosolization of dirt, pollen or mold.

Water vapor was observed collecting inside the double-paned window glass in a number of classrooms. This indicates that the water seal is no longer intact. Water penetration through window frames can lead to mold growth under certain conditions. Repairs of window leaks are necessary to prevent further water penetration.

Other Concerns

Several other conditions were noted during the assessment, which can affect indoor air quality. The abandoned ventilation system can serve as a pathway for basement particulates and odors to migrate into occupied areas of the building. Holes in walls and ceilings may also serve as pathways for particulates (see Picture 9). In general, cold air migrates to areas with heated air, thereby creating drafts. The temperature in the heating coil room will generally be lower than the occupied areas of classrooms, therefore colder basement air will move to classrooms via the vent system if means of access (holes, open access doors) exist in the ductwork.

A number of classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs) (e.g. methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999). Dry erase board markers and cleaners contain chemicals that can be irritating to the eyes, nose and throat of sensitive individuals.

In an effort to reduce noise from sliding chairs and tables, tennis balls are sliced open and placed on chair legs. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gas VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g. spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix II (NIOSH, 1998).

The exhaust system ventilation shafts (see Picture 10) do not appear to have bird screens. In addition, an attic vent appears to be damaged in a manner to allow for pest entry (see Picture 11). Bird and bat wastes are associated with molds (*Histoplasma capsulatum)* (CDC, 2001; NIOSH, 1997) and are of concern for immune compromised individuals. To prevent roosting of birds and bats in these areas, entryways should be secured with bird screens.

Classrooms contained a number of conditions that may attract rodents. Stored food containers were noted in some classrooms. Food residue that remains in containers can serve as an attraction for pests. Under current Massachusetts law (effective November 1, 2001) the principles of integrated pest management (IPM) must be used to remove pests in state buildings (Mass Act, 2000). Pesticide use indoors can introduce chemicals into the indoor environment that can be sources of eye, nose and throat irritation. The reduction/elimination of pathways/food sources that are attracting these insects should be the first step taken to prevent or eliminate infestation.

Conclusions/Recommendations

The abandonment/alteration of the original ventilation system and its components has essentially removed any means to provide mechanical ventilation for the building. Minimization of airflow into the building can result in environmental pollutants concentrating in occupied areas due to the lack of dilution and/or removal by the ventilation system. In order to address the conditions listed in this assessment, the recommendations made to improve indoor air quality are divided into **short-term** and **long-term** corrective measures. The short-term recommendations can be implemented as soon as practicable. Long-term solution measures are more complex and will require planning and resources to adequately address overall indoor air quality concerns.

In view of the findings at the time of this assessment, the following **Short-Term** recommendations are made:

1. Use open windows and hallway doors to enhance airflow during warm weather. Be sure to close windows and doors at the end of the school day. To aid in the draw of fresh outdoor air in warm weather, use portable fans directing air out windows on the leeward side of the building. Fans positioned in this manner will serve to increase the draw of outdoor air across a floor without interfering with the natural, internal airflow

pattern of the building. To aid cross ventilation, open hallway doors in areas with inoperable transoms.

2. Examine the feasibility of restoring the original ventilation system in the basement. This restoration may include removal of asbestos insulation from pipes inside the fan room.
3. If original mechanical ventilation systems are not fully restored, ensure abandoned exhaust and supply vents are properly sealed in classrooms, the basement and on the roof to eliminate pathways for movement of odors and particulates into occupied areas.
4. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
5. Install bird screens on roof top airshafts. Repair damage vent grill in attic (see Picture 11).
6. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation.
7. Replace missing ceiling tiles and fill utility holes in classrooms (e.g. around radiator pipes), to prevent the egress of odors, dust and particulate matter between areas.

8. It is highly recommended that the principles of integrated pest management (IPM) be used to prevent of pest infestation. A copy of the IPM recommendations can be obtained from the Massachusetts Department of Food and Agriculture (MDFA) website at the following website: http://www.state.ma.us/dfa/pesticides/publications/IPM_kit_for_bldg_mgrs.pdf. Activities that can be used to eliminate pest infestation may include the following activities:
   a) Do not use food as components in student artwork.
   b) Rinse out recycled food containers. Seal recycled containers in a tight fitting lid container to prevent rodent access.
   c) Remove non-food items that rodents are consuming.
   d) Stored foods in tight fitting containers.
   e) In areas were food is consumed; periodic vacuuming to remove crumbs is recommended.
   f) Regularly clean crumbs and other food residues from ovens, toasters, toaster ovens, microwave ovens, coffee pots and other food preparation equipment.
   g) Holes as small as ¼" are enough space for rodents to enter an area. Examine each room and the exterior walls of the building for means of rodent egress and seal. If doors do not seal at the bottom, install a weather strip as a barrier to rodents.
   h) Reduce harborages (cardboard boxes) where rodents may reside (MDFA, 1996).
9. In order to maintain a good indoor air quality environment in the building, consideration should be given to adopting the US EPA document, "Tools for

Schools" as recommended by the Athol Board of Health. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.

10. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

Long Term Recommendations

1. Consult a ventilation engineer to determine whether the building can be retrofitted with a modern mechanical ventilation system.
2. Survey 1950s classrooms for univent function to ascertain if an adequate air supply exists for each room and make univent repairs as needed. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the restoration and calibration of univent fresh air control dampers.

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Figure 1 **Cross Ventilation in a Building Using Open Windows and Transoms**

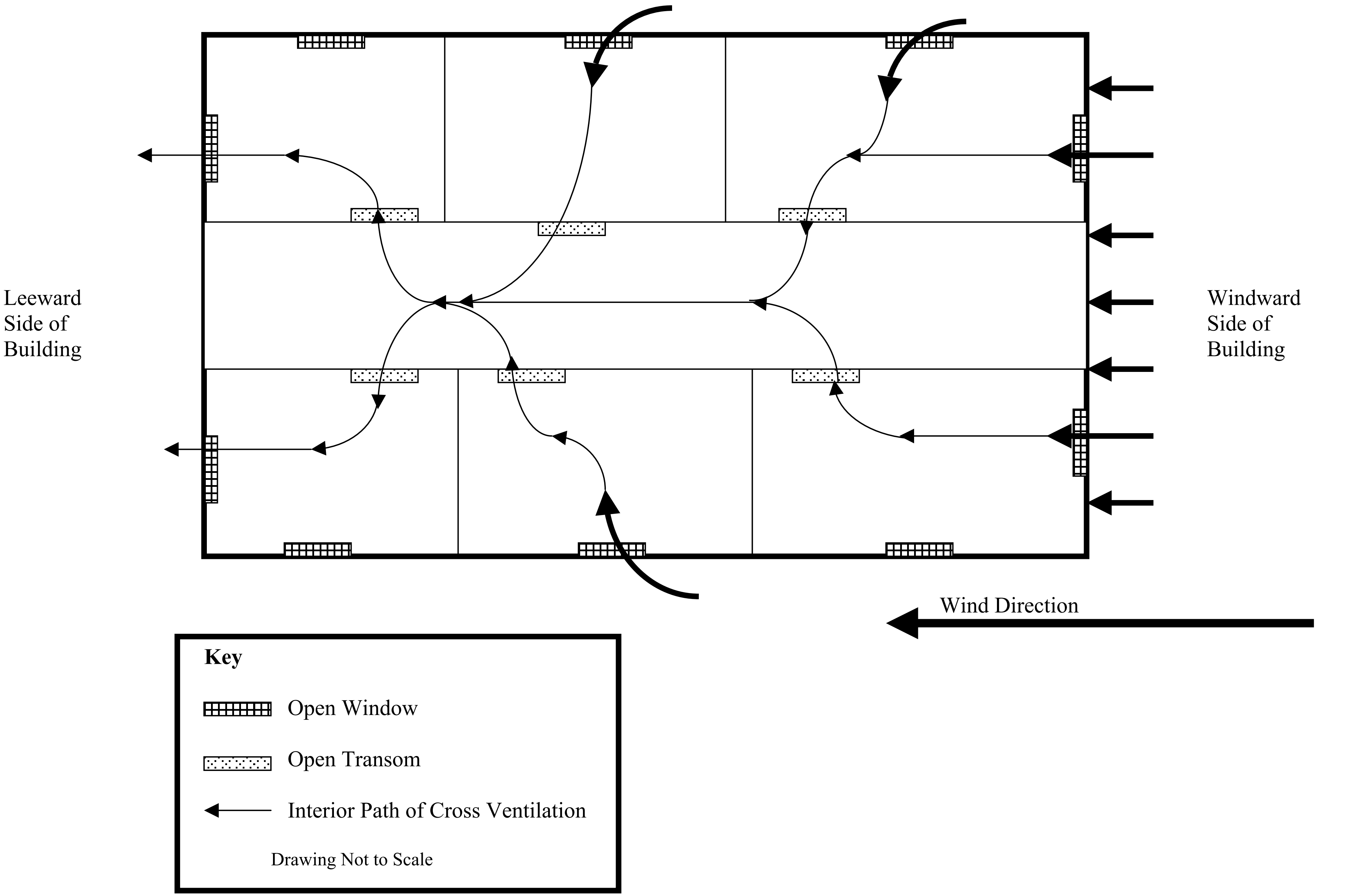
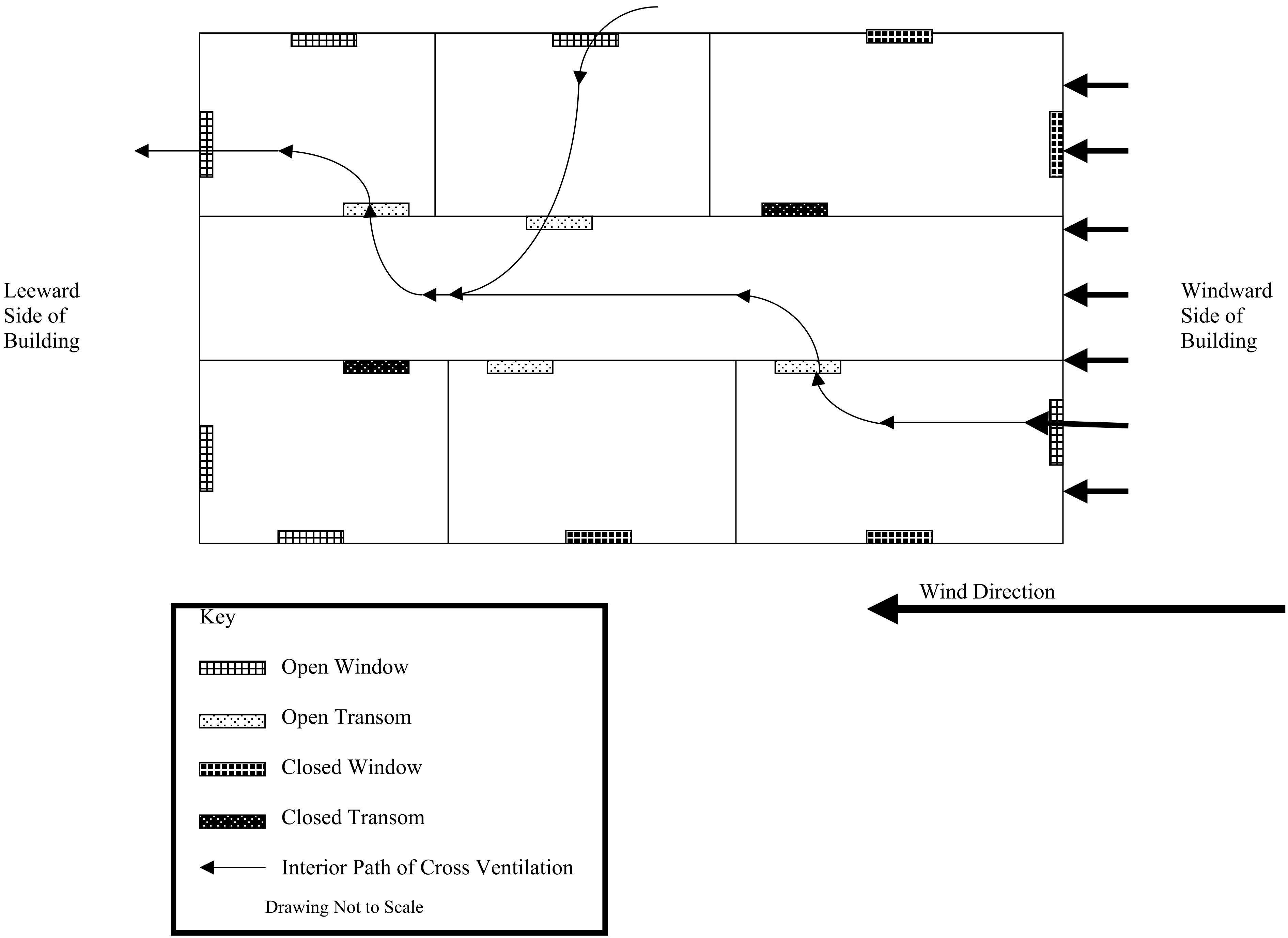


Figure 2 **Inhibition of Cross Ventilation in a Building with Several Windows and Transoms Closed**



Picture 1

Original Fresh Air Intake Sealed by Energy Efficient Windows

Picture 2

Fresh Air Supply Vent 1906 wing

Picture 3

Deactivated Fresh Air Supply Fan in Room Adjacent to Boiler Room, Note Fan Belt is Removed

Picture 4

Transom over Classroom Door

Picture 5

Typical Classroom Univent

Picture 6

Univent Fresh Air Intake Sealed with Plywood

Picture 7

Historic Plaster Damage from Roof Leak

Picture 8

Plaster Damage from Heating System Steam

Picture 9

Utility Hole in Ceiling for Pipes

Picture 10

Exhaust Vents without Bird Screens

Picture 11

Damaged Vent under Attic Window

TABLE 1

Indoor Air Test Results –Riverbend Elementary School, Athol MA — April 11, 2003

Location	Carbon Dioxide *ppm	Carbon Monoxide	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
							Supply	Exhaust	
Outdoors (Background)	319	5	42	31					cloudy
Room 4	594	5	68	36	24	Y	Y	Y	white board, window and door open tennis balls ammonia cleaner
Room 5	968	6	70	28	20	Y	Y	Y	plants white board
Room 6	823	6	73	28	20	Y	Y	Y	white board
Room 7	767	7	72	24	22	Y	Y	Y	white board
Room 11	1021	6	73	27	18	Y	Y	Y	white board, window open plants clutter
Room 12	1084	7	74	27	23	Y	Y	Y	
Room 13	912	6	75	20	18	Y	Y	Y	window and door open white board
Room 14	867	6	75	25	23	Y	Y	Y	white board
10 out	1071	6	75	25	23	Y	Y	Y	white board

*** ppm = parts per million parts of air**
white board = wall erase board

Comfort Guidelines

Carbon Dioxide - < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems
Temperature - 70 - 78 °F
Relative Humidity - 40 - 60%

TABLE 1

Indoor Air Test Results –Riverbend Elementary School, Athol MA **April 11, 2003**

Location	Carbon Dioxide *ppm	Carbon Monoxide	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
							Supply	Exhaust	
10 in	1106	6	73	26	3	Y	N	Y	ammonia cleaner white board
Art Room 8	890	6	70	27	0	Y	Y	Y	white board window open
Room 9	919	6	70	27	9	Y	Y	Y	plants, white board window and door open
Room 1	762	6	70	28	0	Y	Y	Y	white board exhaust blocked by recycle bin
Room 2	1533	6	71	32	23	Y	Y	Y	white board
Room 3	917	6	71	27	10	Y	Y	Y	white board condensation within double-paned window
Kitchen	803	6	72	31	4	Y	Y	Y	door open
Dishwasher Room	668	6	72	37	1	Y	Y	Y	door open
Cafeteria	717	6	72	28	50+	Y	Y	Y	kitchen hood
Boiler Room	401	5	72	23	0	N	Y		combustion air vent (supply)
Computer Room	555	6	71	24	0	Y	N	N	8 computers

*** ppm = parts per million parts of air**
white board = wall erase board

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1

Indoor Air Test Results –Riverbend Elementary School, Athol MA **April 11, 2003**

Location	Carbon Dioxide *ppm	Carbon Monoxide	Temp °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
							Supply	Exhaust	
Teachers Room	746	5	71	26	7	Y	N	Y	empty soda cans refrigerator
Music Room	486	5	71	25	0	0	N	Y	white board

*** ppm = parts per million parts of air**
white board = wall erase board

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
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Temperature -	70 - 78 °F
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